PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 :
C25D 5/00, 5/02, 17/12

A1

(11) International Publication Number: WO 95/20064

(43) International Publication Date: 27 July 1995 (27.07.95)

(21) International Application Number: PCT/US95/01141

(22) International Filing Date: 24 January 1995 (24.01.95)

(30) Priority Data:
08/185,468 24 January 1994 (24.01.94) US

(71)(72) Applicant and Inventor: BERG, N., Edward [US/US]; 43 Smith Road, Bedford, NH 03110 (US).

(74) Agent: SOLOWAY, Norman, P.; Hayes, Soloway, Hennessey, Grossman & Hage, P.C., 175 Canal Street, Manchester, NH 03101 (US).

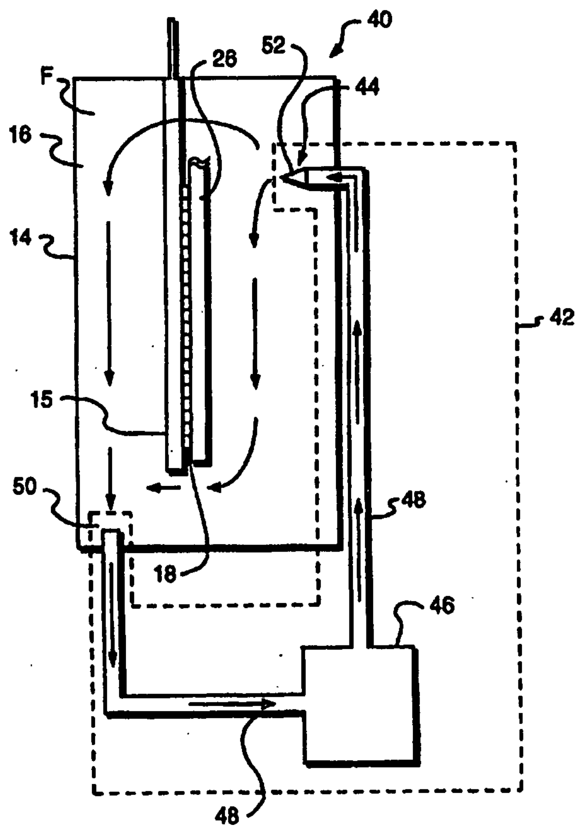
(81) Designated States: CA, JP, KR, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: UNIFORM ELECTROPLATING OF PRINTED CIRCUIT BOARDS

(57) Abstract

A method and apparatus for the uniform electroplating of printed circuit boards is described. In one embodiment of the present invention, selected areas of the electroactive surface of the anode (15) or cathode electrode (26) are covered with a mask (18), whereby to establish substantially uniform electroplating ion transfer over the target areas of the target cathode (26).



FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria	GB	United Kingdom	MR	Mauritania
AU	Australia	GE	Georgia	MW	Malawi
BB	Barbados	GN	Guinea	NE	Niger
BE	Belgium	GR	Greece	NL	Netherlands
BF	Burkina Faso	HU	Hungary	NO	Norway
BG	Bulgaria	IE	Ireland	NZ	New Zealand
BJ	Benin	IT	Italy	PL	Poland
BR	Brazil	JP	Japan	PT	Portugal
BY	Belarus	KE	Kenya	RO	Romania
CA	Canada	KG	Kyrgystan	RU	Russian Federation
CF	Central African Republic	KP	Democratic People's Republic of Korea	SD	Sudan
CG	Congo			SE	Sweden
CH	Switzerland	KR	Republic of Korea	SI	Slovenia
CI	Côte d'Ivoire	KZ	Kazakhstan	SK	Slovakia
CM	Cameroon	LI	Liechtenstein	SN	Senegal
CN	China	LK	Sri Lanka	TD	Chad
CS	Czechoslovakia	LU	Luxembourg	TG	Togo
CZ	Czech Republic	LV	Latvia	TJ	Tajikistan
DE	Germany	MC	Monaco	TT	Trinidad and Tobago
DK	Denmark	MD	Republic of Moldova	UA	Ukraine
ES	Spain	MG	Madagascar	US	United States of America
FI	Finland	ML	Mali	UZ	Uzbekistan
FR	France	MN	Mongolia	VN	Viet Nam
GA	Gabon				

UNIFORM ELECTROPLATING OF PRINTED CIRCUIT BOARDS

This invention relates to electroplating or electro-deposition of metal on a target. The invention has particular utility in connection with electro-deposition of metal onto printed circuit boards or panels and will be described in connection with such utility, although other utilities are contemplated.

Electroplating is an established process of producing a metallic coating on a surface. Such coatings may perform a protective function to prevent corrosion of the metal on which they are deposited, e.g., plating with zinc or tin (electro-galvanizing); or a decorative function, e.g., gold or silver plating; or both functions, e.g., chromium plating.

The principal of electroplating is that the coating metal is deposited from an electrolyte, typically an aqueous acid or alkaline solution, onto a target substrate or panel. The latter forms the cathode (negative electrode) while a plate of the metal to be deposited serves as the anode (positive electrode). Alternatively, the anode may be made of an electrochemically inert (that is, not subject to decomposition during electroplating) metal and the plating metal may be deposited onto the cathode solely from the electrolytic solution.

Usually, the cathode is coated with an industry standard resist material to prevent plating of those areas of the cathode covered with the resist. After plating of the cathode, the resist pattern is removed, thereby leaving unplated the areas of the cathode that had been covered with the resist. As will be appreciated, such conventional resist patterns are incapable of solving the problems with which the present invention is concerned.

During a standard electroplating process, the periphery of the printed circuit board, i.e., the portions of the printed circuit board adjacent its outer edges,

tends to be at a higher current density than the center of the printed circuit board. Hence, metal deposits more rapidly adjacent the periphery of the printed circuit board than at the center. The result of this is that by the time the metal has deposited at the center of the circuit board to form a desired thickness, the metal deposited adjacent the periphery is at a thickness much greater than the thickness at the center. As a result, the width of depositing metal lines may grow laterally, and the resulting plated lines near the periphery may develop a cross sectional configuration resembling a mushroom.

In U.S. Patent No. 4,828,654, it is reported that by spacing the cathode a relatively large distance from the anode, and by making the effective size of the panel to be plated, i.e. the cathode, larger in size than the anode, there is more uniform distribution of the electroplating field. The more uniformly distributed field causes the metallic ions to be electrolytically deposited at a more uniform rate over the articles in the panel. This prior art arrangement reportedly avoids undesirable uneven plating build-up on the articles at those areas where there is a concentration of the electroplating field. It is also reported that field concentrations occur when the size of the article is smaller than the size of the anode, and results in the edges of the article experiencing a substantially greater build up of metallic ions than the center area of the article. Making the effective size of the cathode (the article to be plated) greater than the size of the anode and spacing the anode a relatively large distance from the cathode, operates to discourage the formation of areas of concentration in the electroplating field and encourages the ion transfer to become more uniform over the entire area of the cathode.

U.S. Patent No. 4,828,654 teaches an anode used in electroplating formed by a plurality of individual anode

segments which can be selectively energized to establish an effective anode size that relates to the size of the article to be electroplated, thereby establishing an electrical field of more uniform characteristics to transfer ions from the anode to the articles at a more uniform deposition rate over the whole surface of the article. By adjusting the effective size of the anode to correspond and relate to the size of the article, the non-uniform deposition rates associated with concentrated localized field reportedly are avoided, and the physical size of the electroplating apparatus can be reduced.

U.S. Patent No. 4,933,061 teaches an electroplating apparatus for electroplating a plurality of items. The patented apparatus includes a tank having a bottom wall and side walls, adapted to hold a predetermined quantity of electrolytic plating solution. A sparger system at the bottom of the tank directs the electrolytic plating solution in an upward direction. A cathode rack supports the items to be electroplated and extends intermediate to the anode plates and upwardly from the sparger system. Strategically placed openings in the anodes and an anode screen in conjunction with the sparger system reportedly act to reduce the plating thickness variance over the rack.

In U.S. Patent No. 5,017,275, there is disclosed an anode structure comprising a resilient anode sheet having an active anode surface, and a support sub-structure for the anode sheet. The anode sub-structure has a pre-determined configuration. By flexing the anode sheet onto the anode sub-structure, so that the anode sheet conforms to the configuration of the anode sub-structure, there reportedly is provided an adequate electrical junction for substantially uniform current distribution.

A collection of the known variables which affect the electroplating process have been set out in detail in the HANDBOOK OF PRINTED CIRCUIT MANUFACTURING by Raymond H.

Clark (1985). Therein it is reported that the factors which effect the electroplating process include:

1. plating pattern geography;
2. panel thickness and size of plated through holes;
3. panel boarders;
4. plating rack;
5. bath chemistry, e.g., concentration of metals and acids, concentration of organic leveling and brightening agents, concentration of contaminants;
6. bath temperature;
7. anode-cathode spacing;
8. anode current density;
9. anode depletion;
10. plating bath agitation;
11. cathode agitation;
12. rectifier consideration; and
13. the skill and experience of the plater.

The present invention provides an improved electroplating system which overcomes the aforesaid and other problems of the prior art which have resulted in less than uniform electroplating and metallic deposition, and in so doing provides substantially uniform distribution of the deposited metal, from item to item in an electroplating process.

In accordance with the present invention, a system for electroplating comprises a receptacle for holding a bath of electroplating solution. An electrically conducting anode electrode is positioned within the receptacle in contact with the bath. In one preferred embodiment, the anode is covered at least in part with one or more electrically non-conductive masks which operate to direct the electric current as it travels through the electroplating solution to distribute over the cross-sectional surface area of a conductive substrate immersed in the electroplating receptacle at a location spaced apart from the anode to establish substantially uniform

electroplating ion transfer over the surface of the substrate. The mask or masks may be in direct contact with the anode, or in close proximity thereto. Completing the system are means for electrically energizing the anode and completing the circuit to the target/cathode.

The overall size of the anode, and the size and shape of the mask or masks, mask openings, number of openings, and location of openings in the non-conductive mask are all selected with reference to the size, target configuration and aspect ratio (anode-to-target) of the article to be electroplated. The distance separating the masked anode from the target panel substrate also is adjusted to promote uniform targeting of the electroplating current.

The present invention also provides a method of electroplating an article with a generally uniform thickness coating. In one preferred embodiment, this method comprises covering the anode electrode at least in part with one or more electrically non-conductive masks having a pattern of openings of predetermined configuration relative to the target cathode whereby to result in substantially uniform deposition over the target during electroplating.

Further features and advantages of the present invention will be apparent from the following detailed description of the invention taken in conjunction with the drawings, wherein like numerals depict like parts, and wherein:

Figure 1 is a perspective view of an electroplating apparatus embodying the present invention;

Figure 2 is a side view of portions of the electroplating system of Figure 1; and

Figure 3 is a view similar to 2, and illustrating an alternative form of electroplating system made in accordance with the subject invention;

Figure 4 is a side view of portions of another preferred embodiment of an apparatus embodying the present invention;

Figure 5 is a side view of portions of a variant of the embodiment of Figure 4;

Figure 6 is a side view of portions of a further variation of the embodiment of Figure 4; and

Figure 7 is a partial side-elevational view of an alternative anode construction for use in the embodiments of Figures 4-6.

Referring to Figures 1 and 2, one embodiment 10 of an electroplating system according to the present invention is illustrated. System 10 includes an outer housing 12 which is preferably formed of an electrically insulating and corrosion-resistant material such as plastic. The housing 12 includes means in the form of a downward extending receptacle 14 for holding a bath of an electroplating solution 16. By way of example, for electroplating copper, bath 16 may comprise a copper sulfate solution commonly referred to as "acid copper". The plastic material of the housing 12 and receptacle 14 resists the toxic and corrosive effects of the bath 16.

The electroplating system 10 includes an anode electrode 15 which preferably is covered at least in part with a non-conductive mask 18 (Figure 2), which will be described in detail below. Mask 18 may be coated directly on the electro-active surface of anode electrode 15 or may comprise a separate element which may be fixed to or suspended in close proximity to the electro-active surface of electrode 15. The anode electrode 15 and mask 18 are suspended from an upper support member 20 which is preferably formed of plastic to resist the corrosive effects of the bath 16 and to provide electrical insulation. The anode electrode 15 and mask 18 are held suspended from the support member 20 by fasteners such as non-corrosive titanium machine screw 22.

The article to be plated typically comprises a printed circuit board 26 which becomes the electrical cathode of the electroplating system during electroplating. The printed circuit board 26, which may be covered with an industry standard resist material (not shown), is suspended in the bath by a clamp 28 which includes a thumbscrew 30 or other similar fastening device for attaching and suspending or supporting the article to be electroplated in the bath. Clamp 28 in turn is mechanically connected to an electrically insulating support member 34. A handle 36 extends above the support member to allow the printed circuit board to be inserted into and removed from the bath 16 at the start and end of the electroplating process.

Completing the system are electrical conductors 29 and 32 for electrically connecting the anode electrode 15 and cathode target 26 to a direct current or quasi direct current electrical energy source 38.

A feature and advantage of the present invention is the ability to substantially and uniformly electroplate the conductor paths, lands and holes of a target printed circuit board. Preferably, this is accomplished by covering selected areas of the electro-active surface of a solid anode 15 with a non-conductive mask 18 which directs the electric current through the electroplating solution so that the metal will be deposited onto the target cathode in a controlled (that is, in a substantially uniform) manner. The overall size of the anode, and the size and shape of the openings, number of openings, and location of the openings in the non-conductive mask are selected with reference to the size and geometry of the target article to be electroplated, with the result that field concentrations at any location on the target article are avoided, thereby achieving a relatively uniform layer of electroplated material.

Typically, the mask generally will have openings which

are substantially the negative of the target article. However, in order to compensate for uneven plating buildup on the target panel periphery, the mask openings corresponding to peripheral areas of the target board preferably should be made relatively smaller than corresponding deposition areas on edges of the target board, while the mask openings corresponding to center areas of the target board preferably should be made relatively larger than the corresponding deposition areas on center areas of the target board. Mask size and shape may be empirically determined using the above criteria. The mask may be applied directly to the anode electro-active surface, for example, by coating, or the mask may comprise a separate element which may be fixed directly to or held in close proximity to the anode electro-active surface, thereby allowing various selected exposed portions of the anode to serve as a source of field concentration for the electroplating process.

The distance between the masked anode and the target printed circuit board should be limited to a relatively short distance, typically 2 to 3.5 inches at normal plating potentials, so that bulk transfer through the electroplating bath does not defeat the masking effect.

Certain changes may be made in the above constructions without departing from the spirit and scope of the invention. For example, as shown in Figure 3, it also is possible to achieve uniform deposition by covering the cathode with one or more non-conductive apertured masks. In such case, the mask or masks should be spaced a short distance, e.g. 1.75 to 3 inches from the cathode. Locating the mask less than 1.75 inches or more than 3 inches from the cathode is not advised and may not achieve uniform deposition.

Other modifications are also possible. For example, as shown in Figure 4, in another preferred embodiment 40 of the present invention similar to that shown in Figures

1-2, the anode 15 is placed in direct contact with mask 18 which is placed in direct contact with cathode 26. Embodiment 40 also includes electrolyte circulation means 42 (shown in dashed lines) which permits controlled circulation or flow F of electrolyte fluid 16 in bath receptacle 14. Circulation means 42 comprises at least one conventional nozzle means 44 connected to a conventional filtered pump 46 which pumps fluid 16 from bath 14 through pipe means 48 (via opening 50 in receptacle 14) to nozzle 44, and thence, back into receptacle 14. Preferably, nozzle means 44 comprises a conventional shuttered aperture 52 for controllably adjusting direction and magnitude of fluid flow from nozzle 44. Advantageously, by appropriately adjusting direction and velocity of the flow of fluid in bath 14, the uniformity and speed of deposition of electroplating material upon cathode 26 may be increased.

Figure 5 shows a variation 60 of the embodiment 40 of Figure 4, in which variation 60 circulating means 42 comprises a plurality of nozzle means 44A . . . 44J configured into two oppositely facing banks 62A, 62B of nozzles on opposite sides of board 26. In this embodiment 60, the nozzles 44A . . . 44J are connected to a common combination pressure manifold and circulatory pump 46. Of course, each of the nozzles 44A . . . 44J or any number of them may be connected to independent pumps and/or pressure manifolds (not shown), without departing from the present invention. Additionally, although only two banks of five nozzles each are shown in Figure 5, it will be appreciated that the number and configuration of nozzles may be varied without departing from this embodiment 60 of the present invention.

Various other modifications are also possible without departing from the present invention. For example, the nozzles 44A . . . 44J of embodiment 60 of Figure 5 may comprise respective conventional shuttered-apertures.

Additionally, as shown in Figure 6, the embodiments shown in Figures 4 and 5 may comprise conventional controllable electromotive means 64A . . . L connected to circulation means 42 to permit the nozzles to move within bath 14. Preferably, electromotive means 64A . . . L are controlled via conventional programmable controller device 66 to move the nozzles according to a predetermined pattern to improve deposition of electroplating material upon cathode 26 by providing appropriate flow F of electrolyte fluid in the bath.

Also alternatively, the embodiments shown in Figures 4-6 may comprise an alternative anode 15A shown in Figure 7. Anode 15A (which preferably is made of an electrochemically inert material) may be used by itself (i.e., without necessitating use of a mask) to accomplish substantially uniform electroplate ion transfer onto the target cathode. Preferably, anode 15A comprises a metallic, fine wire mesh grid 74 having a plurality of relatively small openings (representatively referred to by numeral 72). The dimensions of the openings 72 of grid anode 15A are empirically determined so as to permit substantially uniform electroplate ion transfer onto cathode 26. Preferably, when alternative anode 15A is substituted into the embodiments of Figures 4-6, the anode 15A and cathode 26 are separated from each other by a distance much smaller than 2 to 3.5 inches; preferably, this distance is made such that the anode and cathode almost contact each other. Alternatively, anode 15A may be placed in direct contact with industry standard plating resist on cathode 26.

Additionally, the industry standard plating resist pattern usually placed on cathode 26 prior to the electroplating process may be adjusted using computer simulation techniques so as to aid the mask 18 and/or anode 15A in establishing uniform electroplate ion transfer according to the present invention.

Other modifications may also be possible. It is accordingly intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

CLAIMS

1. In an apparatus for electroplating a target cathode, said apparatus including an anode electrode having an electroactive surface in contact with electrolytic fluid of an electroplating bath, the improvement which comprises at least one electrically non-conductive apertured mask in direct contact with and covering said cathode at least in part whereby to direct electric current through the electroplating solution in a controlled manner onto the target cathode, said anode being placed in direct contact with said mask (26) on said cathode, and means (46) for controllably circulating said fluid of said bath.

2. In an apparatus according to claim 1, the improvement characterized by one or more of the following features:

(a) said circulating means comprises at least one nozzle means (44) for directing flow of said circulating fluid in said bath;

(b) said cathode is interposed between banks of facing nozzle means (44A . . .) for directing flow of said circulating fluid in said bath;

(c) said circulating means comprises at least one nozzle means (44A . . .) having adjustable shutter means for changeably directing flow of said circulating fluid in said bath;

(d) said at least one mask (15A) comprises a plurality of openings (72) which are adjusted to establish substantially uniform electroplate ion transfer onto the target cathode;

(e) said cathode is interposed between two banks of oppositely facing nozzle means (44A . . .) having adjustable shutter means for changeably directing flow of said circulating fluid in said bath; and wherein said circulation means preferably comprises at least one nozzle

means and electromotive means (64A . . .) for controllably moving said nozzle means;

(f) said circulation means comprises a plurality of nozzles connected to a combination pump (64) and manifold for circulating said fluid of said bath, and wherein at least one additional mask preferably is interposed between said anode and said at least one mask of said cathode, said circulation means preferably comprises controllable electromotive means (64A . . .) for controllably moving said nozzle means, and said nozzle means (44A . . .) preferably has shutter means for changeably directing flow of said circulating fluid in said bath; and

(g) said cathode comprises a conventional resist pattern disposed thereon, which pattern is adjusted to aid said at least one mask in establishing substantially uniform electroplate ion transfer to said cathode.

3. In an apparatus for electroplating a target cathode, said apparatus including an anode electrode having an electroactive surface in contact with electrolytic fluid of an electroplating bath, the improvement which comprises said anode being closely spaced from said cathode, said anode including a wire mesh (74) defining a plurality of openings (72) which are dimensioned to permit substantially uniform electroplate ion transfer onto said cathode, and means (46) for controllably circulating said fluid of said bath.

4. In an apparatus according to claim 3, the improvement characterized by one or more of the following features:

(a) said mesh (74) has a grid-like configuration;

(b) said circulating means comprises at least one nozzle means (44 . . .) and electromotive means for controllably moving said nozzle means;

(c) said circulating means preferably further comprises a programmable controller device (46) for permitting predetermined motion of said nozzle means; and

(d) said cathode comprises a conventional resist pattern disposed thereon, which pattern is adjusted to aid in establishing substantially uniform electroplate ion transfer to said cathode.

5. In a process for electroplating a target cathode using an apparatus including an anode electrode having an electroactive surface in contact with electrolytic fluid of an electroplating bath, the improvement which comprises placing at least one electrically non-conductive apertured mask in direct contact with and covering said cathode at least in part whereby to direct electric current through the electroplating solution in a controlled manner onto the cathode, placing said anode in direct contact with said mask on said cathode, and controllably circulating said fluid of said bath so as to permit substantially uniform electroplating ion transfer onto said cathode.

6. In a process for electroplating according to claim 5, the improvement characterized by one or more of the following features:

(a) said fluid circulation is accomplished, at least partially, by directing flow of said fluid through at least one nozzle means, preferably by moving said nozzle means according to a predetermined pattern;

(b) said fluid circulation is accomplished, at least partially, by directing flow of said fluid through at a plurality of nozzle means, preferably by moving said nozzle means according to a predetermined pattern.

7. In a process for electroplating a target cathode using an apparatus including an anode electrode having an electroactive surface in contact with electrolytic fluid of an electroplating bath, the improvement which comprises forming said anode so as to include a wire mesh defining a plurality of openings which are dimensioned to permit

substantially uniform electroplating ion transfer onto said cathode, placing said anode in close proximity to said cathode, and controllably circulating said fluid in said bath.

8. In a process according to claim 7, the improvement characterized by one or more of the following features:

(a) said mesh has a grid-like configuration;

(b) said circulation of said fluid is accomplished, at least in part, by directing said fluid through at least one nozzle means, preferably by moving said nozzle means in said bath, preferably wherein said movement of said nozzle means is predetermined;

(c) further comprising adjusting formation of a conventional resist pattern disposed upon said cathode so as to aid said at least one mask in establishing substantially uniform electroplate ion transfer to said cathode; and

(d) further comprising adjusting formation of a conventional resist pattern disposed upon said cathode so as to aid said at least one mask in establishing substantially uniform electroplate ion transfer to said cathode.

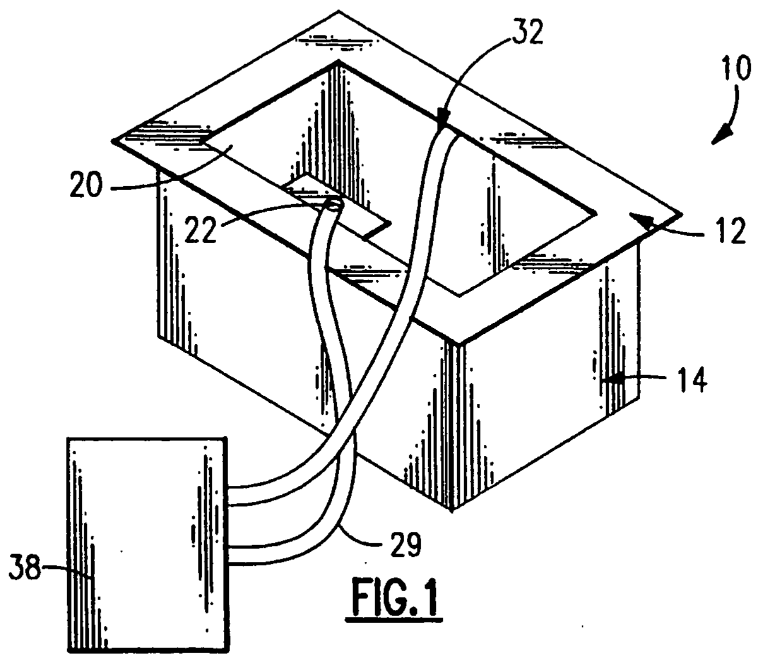


FIG.1

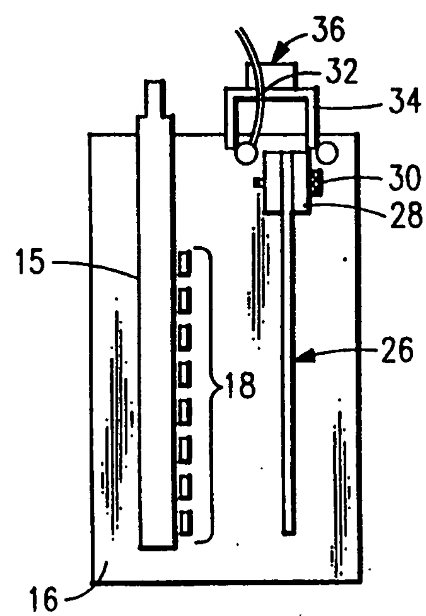


FIG.2

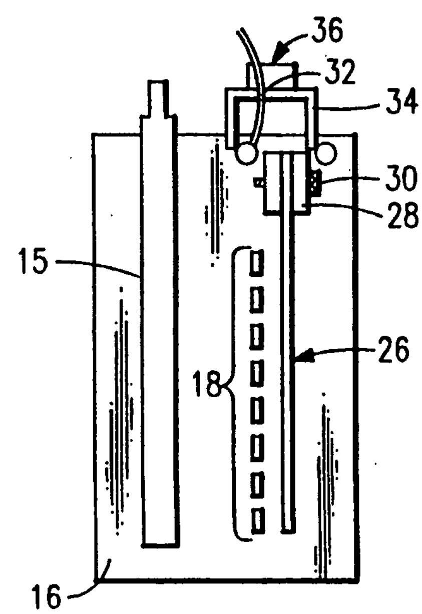


FIG.3

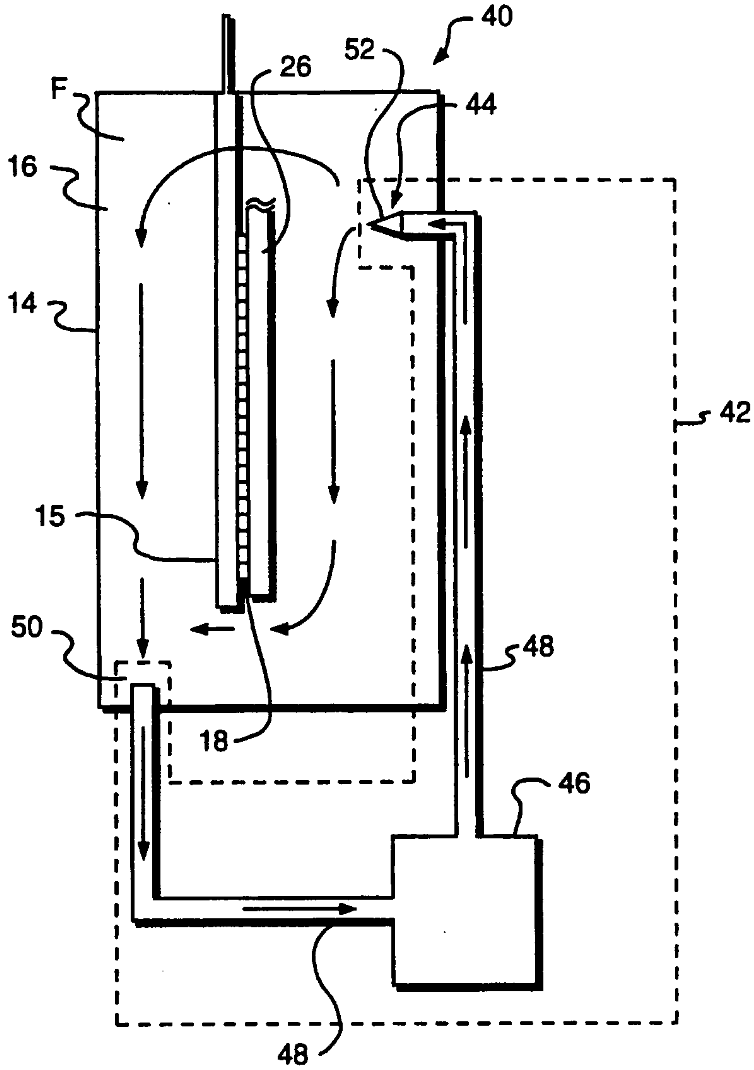


FIG. 4

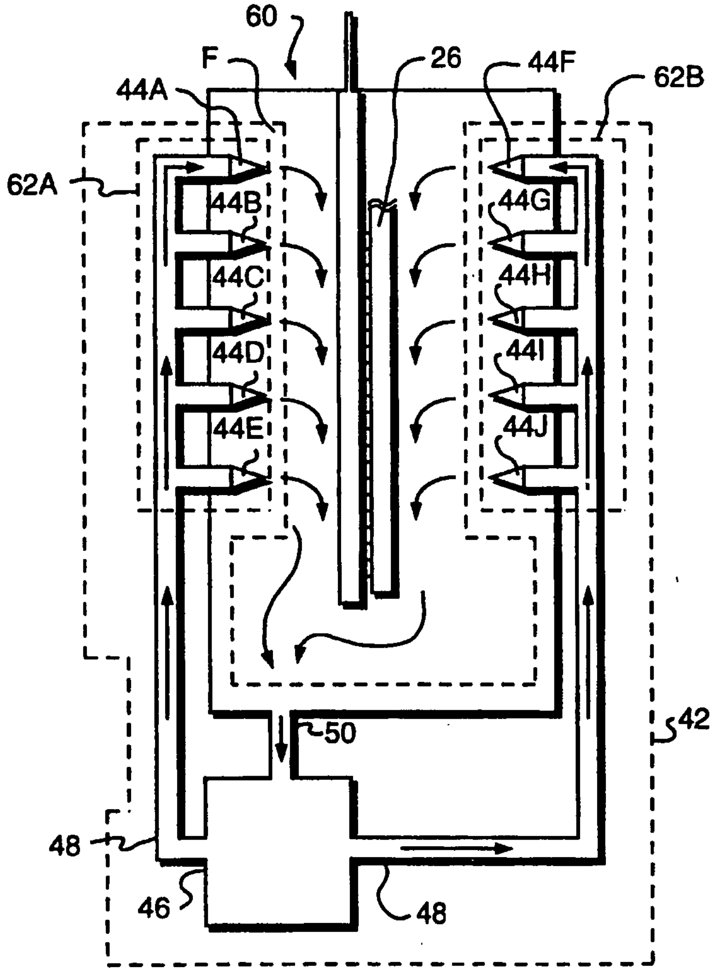

60
F
26
44F
62B
44A
62A
44B
44G
44C
44H
44D
44I
44E
44J
50
42
48
46
48

FIG. 5

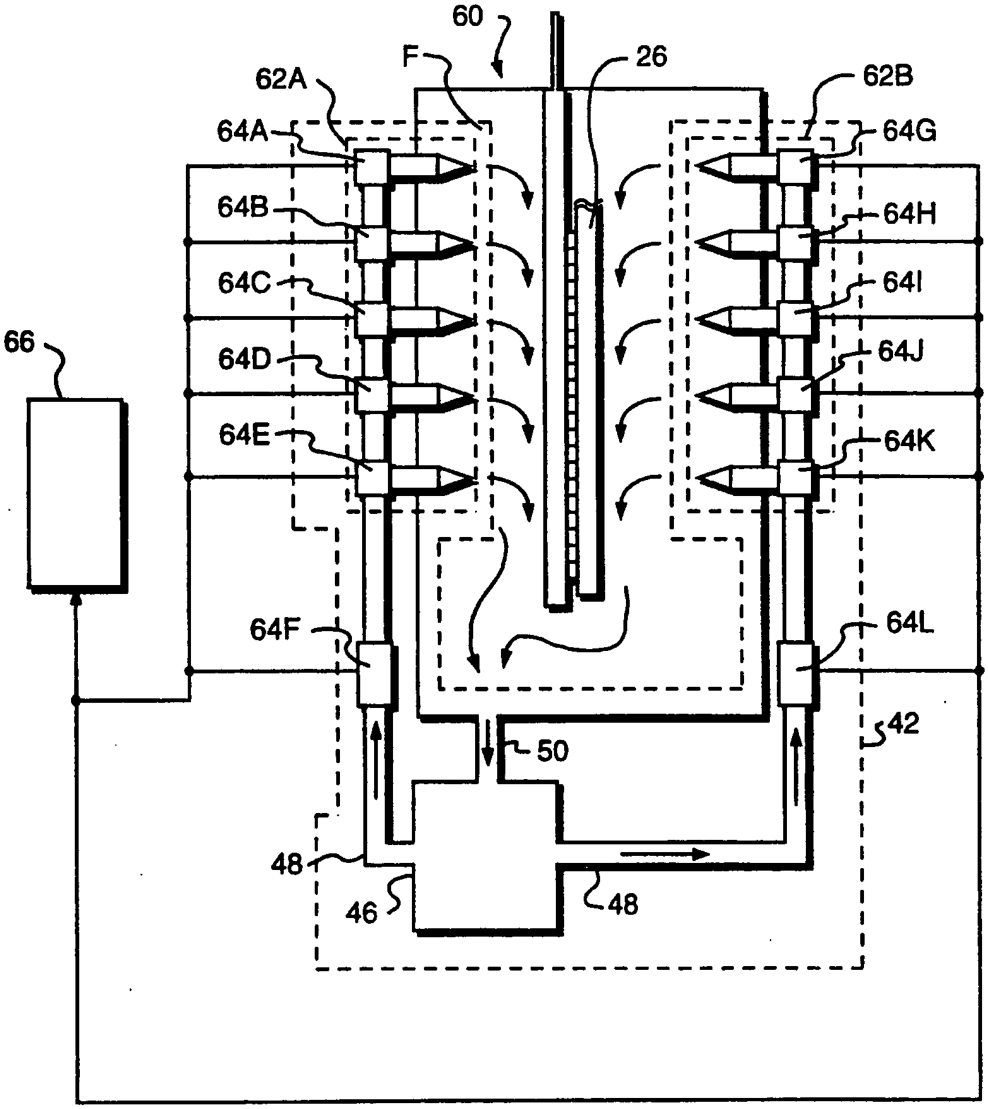

60
F
26
62A
62B
64A
64G
64B
64H
64C
64I
64D
64J
64E
64K
66
64F
64L
42
50
48
46
48

FIG. 6

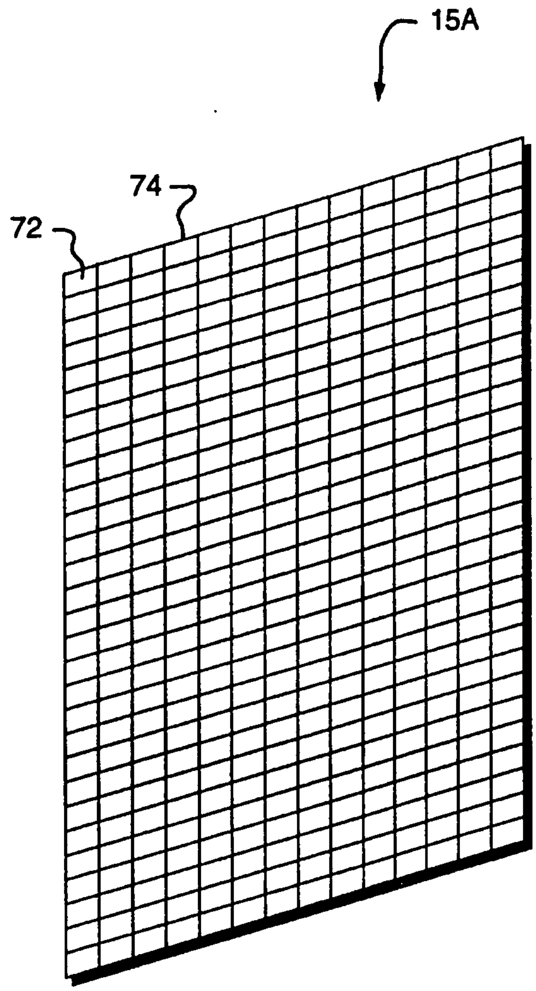


FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US95/01141

A. CLASSIFICATION OF SUBJECT MATTER
IPC(6) :C25D 5/00, 5/02, 17/12
US CL :204/224R; 205/96
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 204/224R, 237; 205/96, 118, 125, 126, 135

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
APS
circuit board or printed circuit, mesh anode, current distribution

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, A, 3,008,892 (OWEN) 14 November 1961, column 2, lines 1-19, figures 1-3.	1, 2, 5, 6
Y	US, A, 3,503,856 (BLACKMORE) 31 March 1970, column 2, lines 59-64, figures 1 and 2.	1-8
Y	US, A, 3,835,017 (MENTONE ET AL) 10 September 1974, column 3, lines 2-8, figure 2.	1-8
A	US, A, 3,962,047 (WAGNER) 08 June 1976.	1-8
X	US, A, 4,220,506 (SKURKISS ET AL) 02 September 1980, column 3, lines 20-26, figures 1 and 3.	3, 4, 7, 8
X	US, A, 4,394,241 (SCANLON) 19 July 1983, column 4, lines 8-60, figures 3 and 4.	3, 4, 7, 8

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 JUNE 1995	05 JUL 1995

Name and mailing address of the ISA/US	Authorized officer
Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	JOHN NIEBLING
Facsimile No. (703) 305-3230	Telephone No. (703) 308-3325